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Bench and Pilot Scale Testing of Aerobic Biological and Advanced Oxidation Process Treatment Methods for Chlorinated Constituents and 1,4-Dioxane in Steam Enhanced Extraction Condensate

Overview

Treatment Evaluation Summary

Steam enhanced extraction (SEE) is a proven remedial technology for dense non-aqueous phase liquid (DNAPL) and volatile organic compound (VOC) contaminated sites. SEE was evaluated for in situ source treatment at a former chemical manufacturing facility in Mississippi. The evaluation included extensive treatment testing of groundwater and condensate which would be generated as a result of SEE source reduction operations.

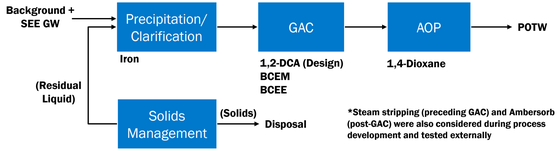
Site Description/Background

- Former specialty chemicals and adhesives manufacturing plant in Moss Point, MS
- Constituents of primary concern include:
  - 1,2-dichlorethane (1,2-DCA)
  - 1,4-dioxane
  - 2-chloroethanol
  - bis(2-chloroethoxy)methane (BCEE)
  - bis(2-chloroethyl)ether (BCEE)
- An interim measure groundwater treatment system (GWTS) treats recovered groundwater for iron (aeration/pH adj) and 1,2-DCA (GAC)
- SEE would significantly increase flow rate and concentrations of primary constituents of concern, requiring augmentation of GWTS

Site Location Plan

Parameter	Units	Routine	SEE Operations	Treatment Target
Flow Rate	gpm	50	270	--
1,2-DCA	µg/L	100	23,500	180
1,4-Dioxane	µg/L	150	4,100	150
2-Chloroethanol	µg/L	Low	118,000	1,000
BCEM	µg/L	3,900	43,700	110
BCEE	µg/L	180	310	1.0
COD	mg/L	25	370	--
Iron	mg/L	100	200	--

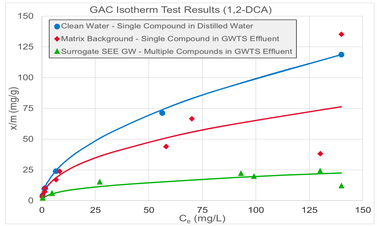
Initial SEE GW Treatment Concept*



*Steam stripping (preceding GAC) and Ambersorb (post-GAC) were also considered during process development and tested externally

Treatment Testing – GAC

GAC Isotherm Studies



Freundlich Model:
$x/m = K_f C_e^{1/n}$

x/m = mass adsorbed per mass adsorbent

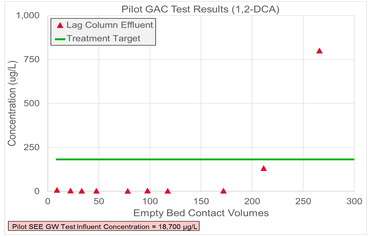
C_e = equilibrium concentration

Isotherm Test Results Summary

Constituent	Clean Water		Matrix Background		Surrogate SEE GW	
	K_f	1/n	K_f	1/n	K_f	1/n
1,2-DCA	9.2	0.52	7.9	0.46	2.8	0.42
1,4-Diaxane	1.3	0.59	0.89	0.54	0.20	0.40
2-Chloroethanol	0.52	0.69	0.28	0.76	0.21	0.72
BCEM	54	0.35	32	0.40	29	0.38
BCEE	28	0.61	18	0.54	1.8	0.42

- General GAC adsorptive capacity established for the primary constituents of concern
- Significant matrix/ competitive adsorption effects observed

GAC Column Studies



Column Test Results Summary

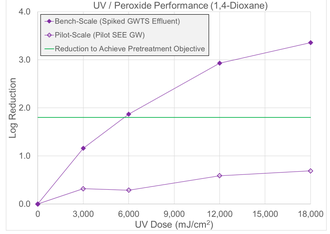
Constituent	Estimated GAC Utilization (lb/yr)
1,2-DCA (Governs)	2,800,000
BCEM	1,000,000

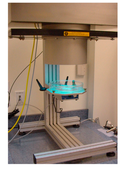
Treatment Testing – AOP

Test Water

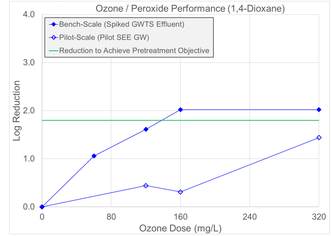
Study	Water	Compound Mix	Concentration (µg/L)
Bench-Scale (Xylem-Wedeco)	GWTS Effluent (Spiked)	1,4-Dioxane 1,2-DCA 2-Chloroethanol	5,000 3,500 3,500
Pilot-Scale	Pilot SEE GW	SEE Operations Characteristics	

UV/Peroxide





Ozone/Peroxide



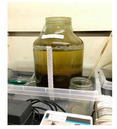
Conclusions – AOP Testing

- General dosing requirements were established to attain target level of removal for 1,4-dioxane
- UV/peroxide provided better removal in spiked GWTS effluent, but was more susceptible to inhibition due to greatly increased organic loading associated with actual SEE GW

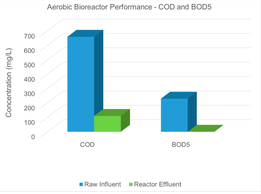
Testing and Results – Aerobic Biological Treatment

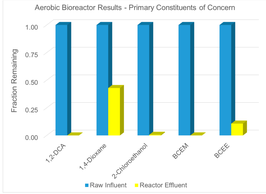
Bioreactor Overview

Reactor ID	Type	Volume (L)	SRT (d)	HRT (d)
Test	SBR	4	20	4
Mother	Fill-and-Draw	16	20	20



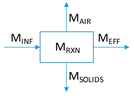
Test Bioreactor Performance



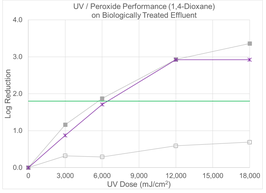


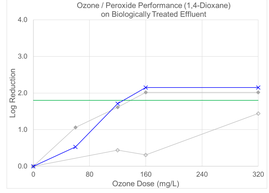
Percent of Influent Mass Attributable to Removal by Biological Reaction

Compound	1,2-DCA	1,4-Dioxane	2-Chloroethanol	BCEM	BCEE
Percent	77	8.0	> 99	> 99	> 87



AOP Testing of Biologically Treated Effluent





Conclusions – Aerobic Biological Treatment

- Removed a majority of SEE GW bulk organic content and individual constituents (including BCEM)
- AOP inhibition which was observed during pilot testing of SEE GW was eliminated
- Biological removal of 1,2-DCA and BCEM would reduce GAC consumption substantially (90% or greater)

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